

# Simulation of Pinatubo aerosols and its impact on stratospheric chemistry by using a CCSR/NIES AGCM

Masayuki Takigawa (Frontier Research System for Global Change, Yokohama, Kanagawa)

Masaharu Ninagawa, Masaaki Takahashi (Center for Climate System Research, University of Tokyo)

Hideharu Akiyoshi (National Institute for Environmental Studies, Ibaraki)

## 1. Introduction

The stratospheric sulfate aerosol layer can scatter shortwave and absorb longwave, and it can play an important role in the stratospheric chemistry by providing a surface for heterogeneous chemistry.

Schematic diagram showing the effect of sulfate aerosols in the stratosphere.

## 2. The objective of this study

By the eruption of Mt. Pinatubo on June 1991, 12–20Mt of sulfur intruded into the lower stratosphere. The quantity of intruded sulfur is estimated about 100 times larger than the nonvolcanic amount. Several numerical experiments have been carried out to study the chemical and radiative effect of the 1991 Pinatubo eruption. However, none of them considered the chemical and radiative effect of volcanic aerosols at the same time. The objective of this study is to answer the question "how much is the warming by Pinatubo eruption at the lower stratosphere by considering heterogeneous reactions on the surface of aerosol and radiative effect of aerosol?", by using the radiative-chemical-dynamical coupled CCSR/NIES AGCM.

## 3. Characteristics of the model

**Horizontal resolution:** T21 (about 5.6 degree)  
**Vertical resolution:** 32 levels (about 2km interval, up to 80km)  
**Radiative Process:** DOM + k–distribution, with using 3-D profiles of 20 chemical species (*e.g.* ozone) and aerosols predicted in the chemical scheme (On-line!)  
**Convective Process:** Simplified Arakawa-Schubert (considering tracer updraft/downdraft)  
**Gravity-wave drag:** McFarlane (1987)  
**Chemical Process:** Based on Takigawa et al. (1999), and modified to treat O<sub>x</sub>–HO<sub>x</sub>–NO<sub>x</sub>–ClO<sub>x</sub>–SO<sub>x</sub> chemistry

- Chemical species:** 36
- Gaseous reactions:** 85
- Heterogeneous reactions:** 4
- Photolytic reactions:** 26

**Aerosol properties:**

- Size distribution:** bimodal lognormal distribution based on balloon–bourne observations
- Composition:** 75wt% sulfuric acid droplet

## 4. Model scenarios

We conducted three series of numerical experiments with climatological SST. EXP1 was for the background case, and only background aerosols were considered. EXP2 and EXP3 were prepared for the simulation of the 1991 Pinatubo eruption. The difference of EXP2 and EXP3 was the treatment of heterogeneous reactions on the surface of sulfate aerosols. The radiative effect of aerosols on longwave/shortwave was taken into account in all scenarios. In each series, we conducted four members of ensemble experiments.

	Radiative Effect	Chemical Effect	Surface Emission	Eruption
EXP1	O	O	O	0 Tg
EXP2	O	O	O	17 Tg
EXP3	O	X	O	17 Tg

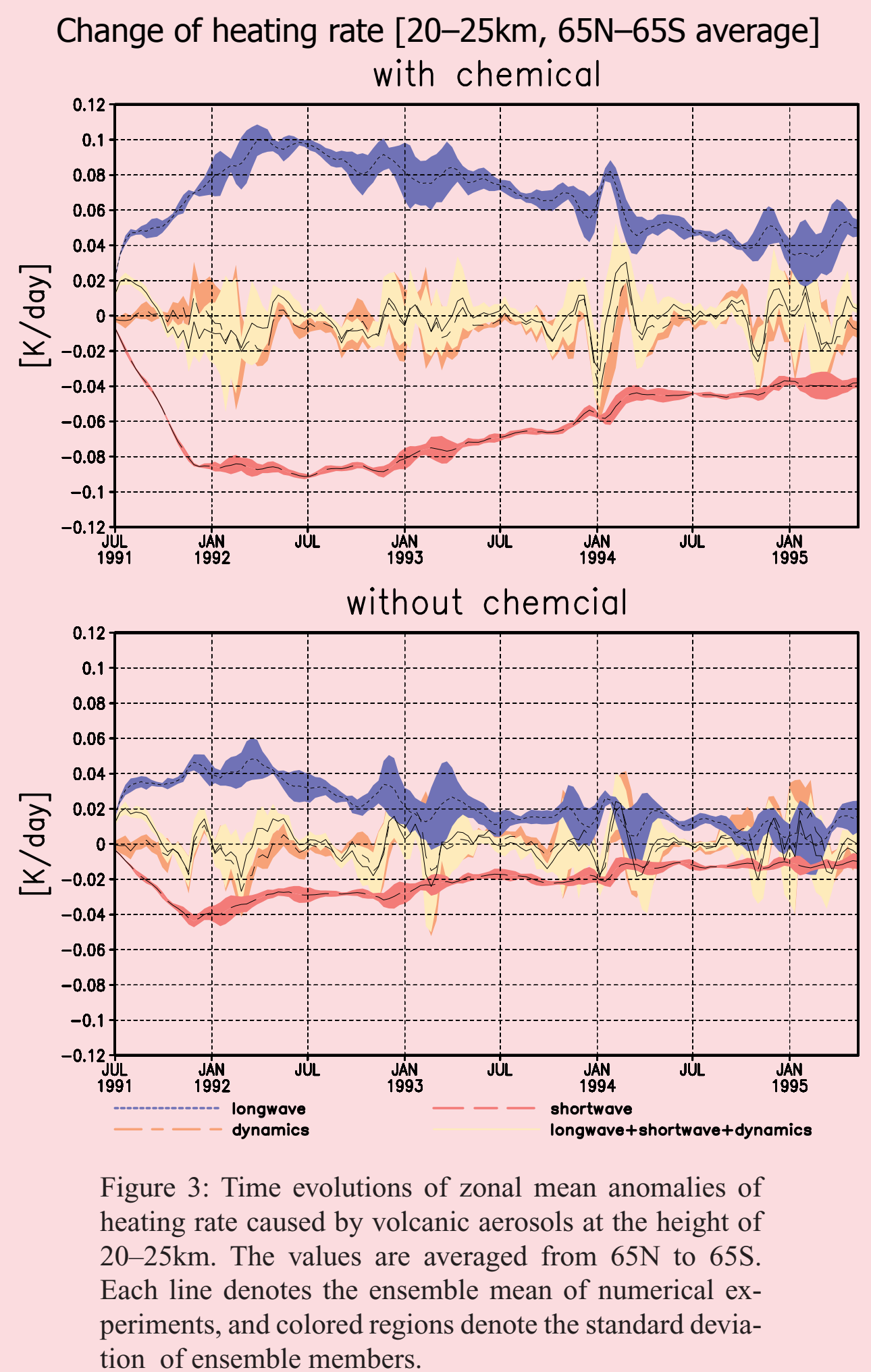
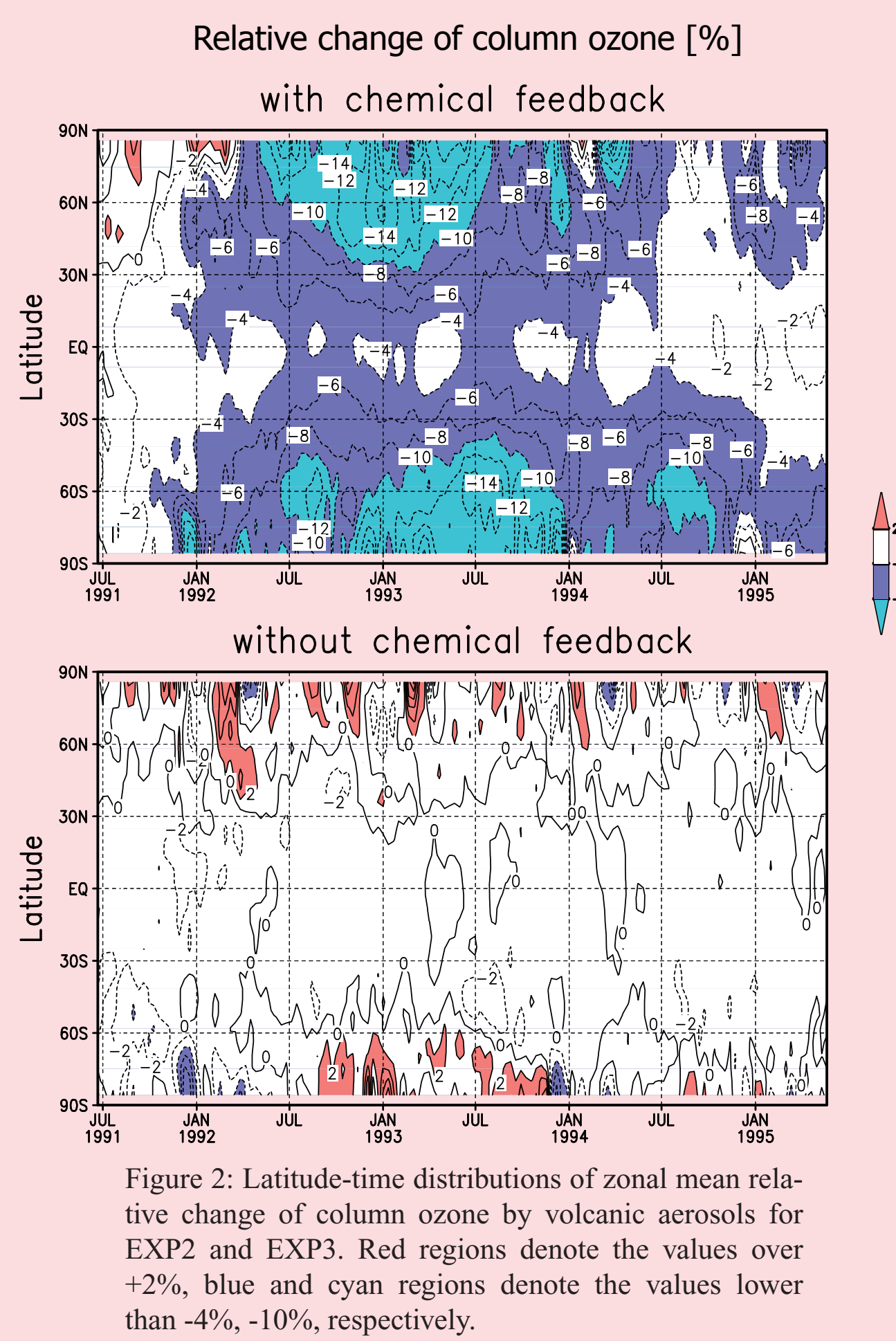
Design of numerical experiments.

### 5.1. Radiative effect of aerosols.

Volcanic SO<sub>2</sub> is rapidly converted into sulfate aerosols. The e–folding time of conversion in the model is estimated to be about 45 days, which is about 10 days longer than that observed. Figure 1 shows the zonal mean column integrated optical thickness for sulfate aerosols. There can be seen a meridional transport of volcanic aerosols. The equatorial values reach the maximum of 0.18 from August to October 1991. The maximum value is similar to that of the SAGE II observation for 550nm (0.18 in the model, 0.20 in the observation).

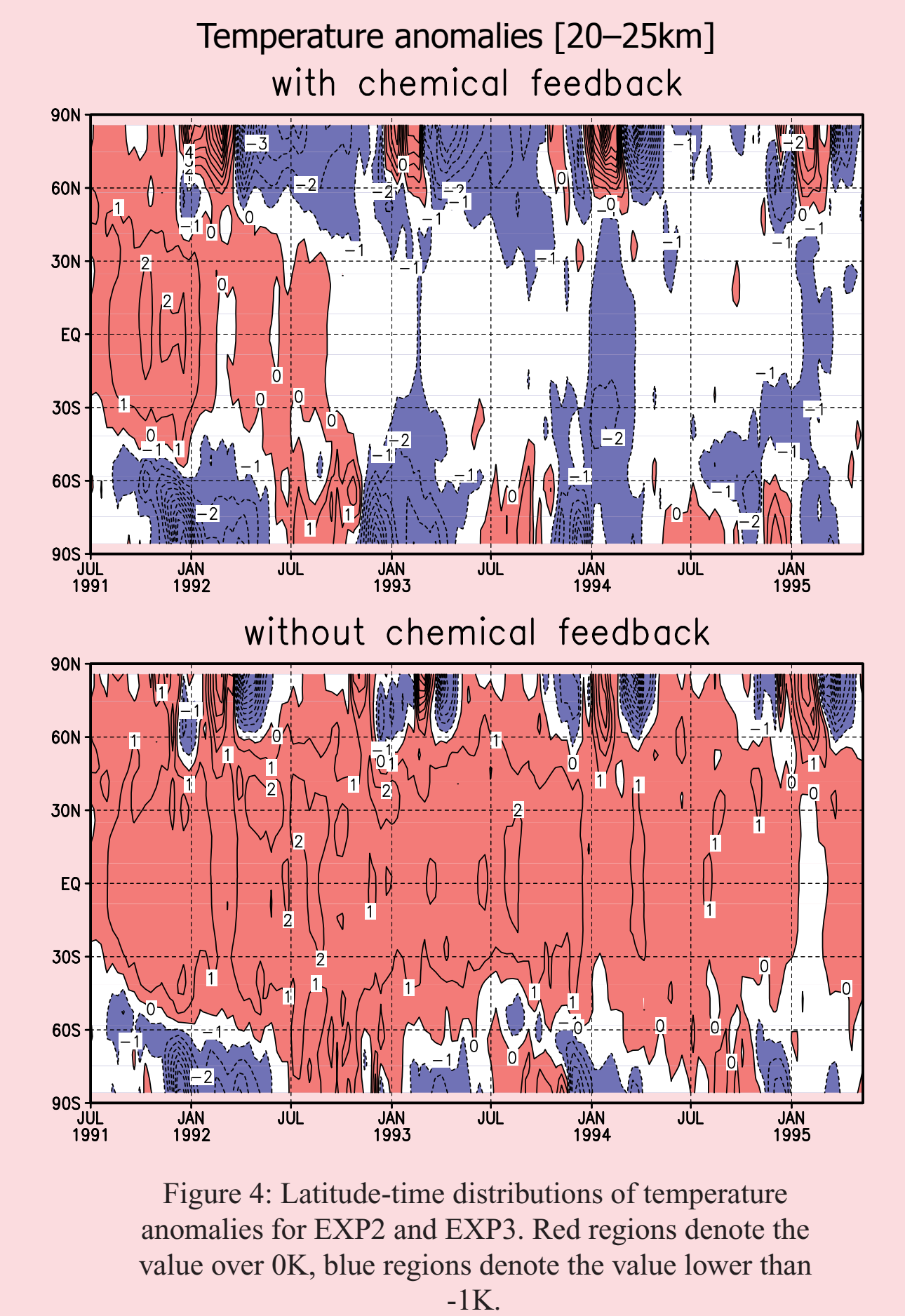
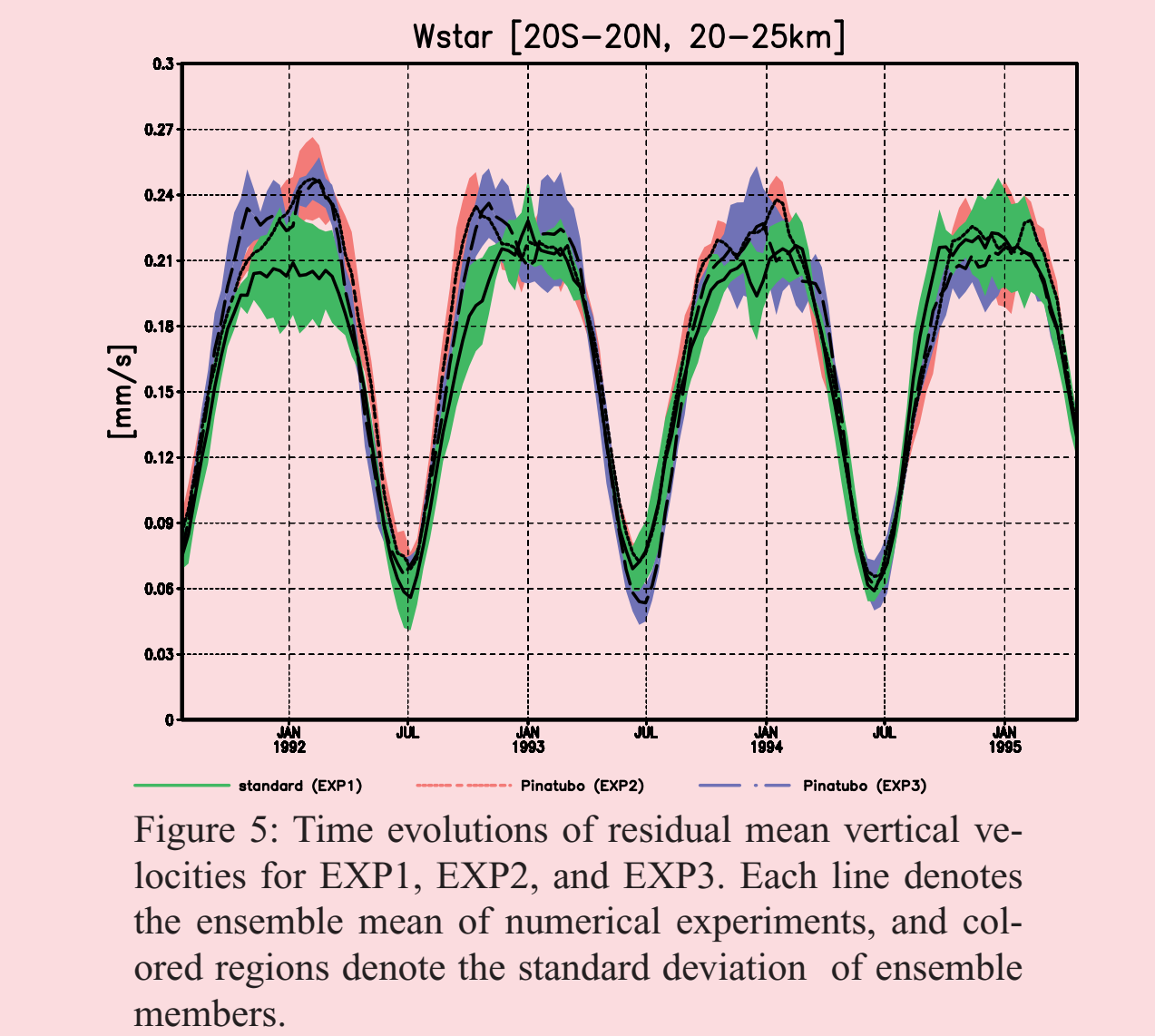
### 5.2. Chemical effect of aerosols.

Volcanic aerosols can change the quantity of chemical species, such as HO<sub>x</sub>, ClO<sub>x</sub>, and NO<sub>x</sub> by heterogeneous reactions on the surface of aerosols. It causes global ozone depletion (Figure 2). Ozone depletion also changes heating rate in the lower stratosphere (Figure 3).



### 5.3. Temperature anomalies

The change of heating rate caused by aerosols and ozone depletion (*c.f.*, Figure 3) leads temperature change in the lower stratosphere (Figure 4). For about a half year after the eruption, there is no evident discrepancy by the consideration of the heterogeneous reaction on volcanic aerosols. The temperature increases in the midlatitudes and tropics with the maximum value of 1–2K. After January 1992, the warming continues until October 1993 in EXP3. In contrast, the warming rapidly disappears in EXP2. The temperature anomaly of satellite observation has the maximum value of about 1.5K at 30N in October 1991. By considering the heterogeneous reaction on the volcanic aerosol, overestimation of the warming disappears. Figure 5 shows the residual mean vertical velocities for EXP1, EXP2, and EXP3. There can be seen an enhancement of the vertical current for about one year after the eruption. The maximum value of enhancement is about 0.01–0.03mm/s, corresponding with the temperature increase of 2K.



## Reference list

Nagashima, T., M. Takahashi, and F. Hasebe, The first simulation for an ozone QBO in a general circulation model, *Geophys. Res. Lett.*, **25**, 3,131–3,134, 1998.

Takahashi, M, Simulation of the stratospheric quasi-biennial oscillation using a general circulation model, *Geophys. Res. Lett.*, **23**, 661–664, 1996.

Takigawa, M., M. Takahashi, and H. Akiyoshi, Simulation of ozone and other chemical species using a Center for Climate System Research/National Institute for Environmental Studies atmospheric GCM with coupled stratospheric chemistry, *J. Geophys. Res.*, **104**, 14,003–14,018, 1999.